

SPECIFICATION

TITLE OF THE INVENTION

**GAS ENGINE ELECTRIC POWER GENERATING SYSTEM EFFECTIVELY
UTILIZING GREENHOUSE GAS EMISSION CREDIT**

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a gas engine electric power generating system to effectively utilize coal mine methane gas which is not only low in methane concentration and large in its variation by the gas engine electric power generating system, which but also serves to smoothly advance the economic development in developing countries by utilizing the profit made by electric power generating and also GHG(greenhouse gas) emission dealing.

Description of the Related Art

In growing awareness worldwide of environmental problem, country-by-country objectives of reduction of carbon dioxide emission were decided at the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change held in 1997 in Kyoto. In the meeting, Kyoto mechanism for the reduction of GHG (CO₂, CH₄, N₂O, etc.) emission in accordance with the conditions of countries and for the promotion of the efficiency of reduction was acknowledged.

Kyoto mechanism is a system to promote worldwide cooperation and emission credit dealing for the reduction of GHG, in which a concept of carbon dioxide emission credit

(right to emit a certain amount of carbon dioxide) was introduced and which aims to utilize market principle as supplementary scheme for achieving the reduction objective of each country. When each entity (nations, enterprises, stores, families, etc.) took action of directly exhausting GHG (for example, consuming of energy for operating machines, consuming of gasoline for running vehicles, etc.) or when it took action of indirectly exhausting GHG (for example, mining of coal, selling of gasoline, etc.), it is assumed that each entity is under an obligation to bear carbon dioxide emission credit corresponding to the exhausted amount of GHG.

As for energy, coal industries of major coal yielding nations of the world (China, CIS, Europe, and the United States, etc.) are prospected to play an important roll as energy suppliers even in the middle part of this century.

However, in proportion to the coal production, methane gas of 10~40Nm³ (in terms of pure methane) per ton of coal is released to the atmosphere as recovered methane gas (30~50% concentration, air diluted) and ventilated methane gas (0.3~0.7% concentration, air diluted). Therefore, technology and business to effectively utilize the methane gas now being released to the atmosphere are very prospective and will make large social and economic contributions.

For example, amount of coal mine methane gas released by countries & districts is; China 14,400(206), CIS 4,200(60), and other developing countries 3500(50) totaling to 22,100(316), which is over twice the total 11,000(157) of developed countries. (Unit is million m³/year, numbers in parentheses are the values converted to carbon dioxide in

million tons/year). To utilize those mine methane gas of developing countries is very advantageous from the point of view of emission credit trade.

There are two kinds of coal mine methane gas as shown in FIG.5, one is recovered methane gas recovered by a vacuum pump from bore holes for degassing for the sake of safety, and the other is ventilated methane gas exhausted together with the ventilation air from the mine shaft and coal seam. The concentration of methane of these gas is low, that of the former is 30~50% and that of the latter is extremely low as 0.3~0.7%.

To use a boiler or gas turbine as a heat engine to utilize methane gas has been considered.

However, if recovered methane gas of methane concentration of 30~50% is to be used for a gas turbine or boiler, as combustion temperature is low and methane concentration varies from time to time, it is not practical. It is recognized difficult to use even the recovered methane gas for a gas turbine. Actually, the usage of recovered methane gas has been limited. It has been used as fuel by the nearby household, or in the case of a boiler used only as auxiliary fuel.

Therefore, as for the utilization of coal mine methane gas, even recovered methane gas is seldom utilized, and almost all of the coal mine methane gas is released to the atmosphere.

However, greenhouse effect index (here and hereafter, this term is identical to "global warming potential") of methane gas is 21 times that in the case the methane gas is burnt and released to the atmosphere as CO₂. For example,

coal mine methane gas release in China is 14.4 billion m³, which is equivalent to more than 10% of total amount of CO₂ release in Japan.

Therefore, if Japan establishes an enterprise to effectively consume the coal mine methane gas in China to change the methane gas to CO₂ and release to the atmosphere as CO₂, reduction of greenhouse effect index of 20 can be achieved in comparison with the case the methane gas is released to the atmosphere, for greenhouse effect index of methane is 21, on the other hand, greenhouse effect index of CO₂ is 1. This reduction of greenhouse effect index can be traded as emission credit.

For example, if developing countries such as China, CIS, etc. start business to effectively consume coal mine methane gas through receiving finance or loan aid from the Asian Development Bank, the World Bank, or ODA of Japan, etc., the enterprising body can make profits from the enterprise and also can make profits by selling CO₂ emission credit to a surcharge payment obligator. This surcharge system is a system that a country(government) for example levies a toll on each enterprise for its releasing of carbon dioxide. There are two methods, one is that the surcharge is added to fuel price, the surcharge being proportional to the amount of carbon dioxide emission calculated from the amount of primary energy, and the other is that the surcharge is levied at the time carbon dioxide is actually released.

SUMMARY OF THE INVENTION

The present invention is made to solve the problem mentioned above, and an object is to provide an art on the

basis of which can be established an enterprise which effectively utilizes coal mine methane gas of low in concentration of methane and large in its variation and which serves to smoothly advance the economic development in developing countries by mortgaging GHG emission credit for financing or loan aid utilizing CO₂ emission credit trade system.

Another object of the present invention is to achieve the above-mentioned object by effectively utilizing the gas engine equipped with a combustion diagnosis apparatus that the present applicant developed(see WO02/079629).

First, the structure of the principal part of the gas engine used for the present invention will be explained with reference to FIG.1. In FIG.1, the reference numeral 20 is the main body of a gas engine. A pilot fuel ignition device 11 comprising an injection nozzle 11b and a sub-chamber 11c is mounted in the upper part of the combustion chamber 44 formed by a cylinder and piston, flame jet 44a being injected from said sub-chamber 11c into the combustion chamber 44, recovered methane gas and ventilated methane gas being mixed in the inlet pipe 9 before entering into the combustion chamber 44. Reference numeral 41 is the inlet valve.

As the gas engine used in the present invention is a pilot ignition engine and the ignition of the gas fuel in the combustion chamber 44 occurs through the flame jet 44a injected from the sub-chamber 11c, very lean mixture of methane of 10% or lower, preferably 3~5%, or 3~4% can be ignited. Therefore, recovered methane gas of methane concentration of 30~50% and ventilated methane gas of methane concentration of 0.3~0.7% are mixed in the inlet pipe

before entering into the combustion chamber 44 to be reduced to lean mixture of 4~5% methane by means of a combustion control apparatus 200.

In this case, it is preferable to control so that excess air ratio is approximately 2.

With the gas engine, very lean mixture of methane can be ignited and engine performance can be improved.

To cope with the combustion of very lean methane mixture and from time to time changing methane concentration, the gas engine is equipped with a combustion diagnosis apparatus 100, by virtue of which misfire and knocking can be evaded.

In this way, the operation method of a gas engine can be established, by which coal mine methane gas that changes from time to time in methane concentration can be effectively utilized by proper combination of recovered methane gas and ventilated methane gas.

By connecting an electric power generator to the gas engine, profit form electric power production can be made.

The exhaust gas of the gas engine can be utilized for producing steam and then released to the atmosphere. Thus, coal mine methane gas is changed to carbon dioxide by the combustion in the gas engine and released to the atmosphere, so that reduction of greenhouse effect index of 20 can be achieved in comparison with the case the methane gas is released to the atmosphere, for greenhouse effect index of methane is 21, on the other hand, greenhouse effect index of CO₂ is 1. This reduction of greenhouse effect index can be traded as emission credit.

The enterprising body planning to establish the gas engine electric power generating system near a coal mine can

smoothly get fund if carbon dioxide emission credit is mortgaged when the enterprising body makes an application for financing or loan aid to the Asian Development Bank or ODA of Japan, etc. under the condition that the enterprising body establishes the gas engine electric power generating plant at a coal mine, for example, in developing country.

The enterprising body reports to the U.N. or the Japanese Government, etc. of the CO₂ emission reductions to be achieved by the difference 20 of greenhouse effect index of methane and CO₂ and can register this carbon dioxide emission credit on the emission credit market to prepare for trading with credit surcharge payment obligators. There may be the case the purchaser of CO₂ emission credit is other than the Japanese Government.

After getting fund from the Asian Development Bank, etc., the enterprising body pays for principal parts to purchase the principal parts and completes the gas engine electric power generating system.

The enterprising body can get not only profit through selling the electric power produced by the operation of the gas engine electric power generating system, but also can achieve the reduction of 20 times the greenhouse effect index of carbon dioxide. With the profit obtained by selling the carbon dioxide emission credit to surcharge payment obligators on the market, the loan can be refunded in a short period. As a result, the enterprising body can get profit dually and promote smoothly advancing the economic development in developing countries by effectively utilizing CO₂ emission credit, i.e. mortgaging CO₂ emission credit for getting fund or loan aid. There may be the case

that CO₂ emission credit is not necessary as a mortgage for financing or loan aid for the project of establishing the gas engine electric power generating plant, for there may be a fund offerers who invest on the basis of prospective investment return.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a schematic cross-sectional view of the structure of the principal part of the gas engine for utilizing coal mine methane gas in the system according to the present invention.

FIG.2 is a diagrammatic representation showing the total configuration of the gas engine for utilizing coal mine methane gas in the system according to the present invention.

FIG.3 is an example of control flowchart of said gas engine.

FIG.4 is a diagram showing the relation of cylinder pressure to crank angle of said gas engine.

FIG.5 is a conceptual rendering showing a combination of a coal mine methane gas and the system according to the present invention.

FIG.6 is a conceptual rendering showing a business model of carbon dioxide credit trade.

FIG.7 is a table showing the electric power production and carbon dioxide reduction by region when utilizing the business model of FIG.6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be detailed with reference to the accompanying drawings. It

is intended, however, that unless particularly specified, dimensions, materials, relative positions and so forth of the constituent parts in the embodiments shall be interpreted as illustrative only not as limitative of the scope of the present invention.

In FIG.2 showing the total configuration of the gas engine, reference number 20 is the main body of a gas engine, 45 is a piston, 46 is a crankshaft, 44 is a combustion chamber, 41 is an inlet valve, 42 is an exhaust valve, and 43 is an exhaust pipe.

Reference number 9 is an inlet pipe. A recovered methane gas injection device 10 is provided midway along said inlet pipe 9 for injecting recovered methane gas into the ventilated methane gas flowing in the inlet pipe 9.

Reference number 8 is a gas supply pipe for connecting a recovered methane gas tank (not shown) accommodating recovered methane gas and said gas injection device 10. Reference number 7 is a gas supply electromagnetic valve provided at the entrance of said gas supply pipe 8 to enter into said gas injection device 10. A combustion control device 200, which is detailed later, receives the signal of detected methane concentration from a recovered methane gas concentration detector, and said electromagnetic valve 7 is controlled under the control signal from said combustion control device 200 to be shut-off or adjusted of its openings.

Reference number 11 is an ignition device for torch-igniting the pilot fuel oil injected into a sub-chamber(see FIG.1) from a pilot fuel injection valve 0011 to promote the combustion of lean methane gas/air mixture in the main combustion chamber.

The gas pressure in the combustion chamber, i.e. cylinder pressure is detected with a cylinder pressure detector 1, and crank angle is detected with a crank angle detector 2.

Reference number 100 is a combustion diagnosis apparatus composed of a noise filter 3, an amplifier 4 for amplifying the cylinder pressure signal passed through the noise filter, and a combustion diagnosis section 5. The noise filter 3 and amplifier 4 are not necessarily required for constituting the system.

Said noise filter is composed of a low-pass filter for filtering out the noise on the signal inputted from said cylinder pressure detector. Said combustion diagnosis section 5 diagnoses the combustion condition in said combustion chamber 44 on the basis of the cylinder pressure signal amplified by said amplifier 4 with the assistance of the crank angle signal from said crank angle detector 2.

The combustion control device 200 receives the signal of the result of diagnosis at said combustion diagnosis section 5, and shuts off or controls the opening of said gas supply electromagnetic valve 7 and also controls the action of said ignition device 11 based on the diagnosis result signal. The result of diagnosis by the combustion diagnosis section 5 is displayed on a displaying apparatus 6.

On the operation of the methane gas engine of this configuration, when pilot fuel is allowed to ignite in said ignition device 11 and a gas valve(not shown) is unclosed, the recovered methane gas in a recovered methane gas tank(not shown) is supplied to said gas injection device 10, the recovered methane gas being adjusted in pressure by a gas pressure adjusting device(not shown). By the opening of said

gas supply electromagnetic valve 7, the recovered methane gas is injected into the ventilated methane gas flowing through the gas injection device 10 provided midway along said inlet pipe 9 to be mixed with the flowing ventilated methane gas. (The ventilated methane gas may be added with air as necessary.) The mixture is introduced into the combustion chamber 44 through the inlet valve 41 and ignited by the flame jet 44a(see FIG.1) spouting from said ignition device 11 to be burned in the combustion chamber 44.

The working of the combustion diagnosis apparatus will be explained below.

The gas pressure in the combustion chamber 44 detected by said cylinder pressure detector 1 is inputted to the noise filter 3 composed of a super low-pass filter in the combustion diagnosis apparatus 100, high frequency noises are filtered at the noise filter 3, and the cylinder pressure signal smoothed through the filtration is amplified by the amplifier 4 to be inputted to said combustion diagnosis section 5.

To the combustion diagnosis section 5 is also inputted the crank angle signal from said crank angle detector 2.

Next, an example of combustion diagnosis operation by the combustion diagnosis apparatus 100 will be explained with reference to the example of combustion control flowchart shown in FIG.3 and cylinder pressure curve shown in FIG.4.

The cylinder pressure-crank angle curve as shown in FIG.4 is obtained in the combustion diagnosis section 5 from the cylinder pressure inputted from the cylinder pressure detector 1 and the crank angle inputted from the crank angle detector 2.

Curve A in FIG.4 is a cylinder pressure curve when the combustion is normal.

First the compression pressure P_0 at a predetermined crank angle in the compression stroke shown in FIG.4 is compared in a compression pressure judging means(step) with the predetermined permissible compression pressure P_{c0} which is the minimum permissible pressure in the compression stroke, and it is judged that the compression pressure P_0 is abnormally low compared to the normal value due to troubles such as gas leakage or mechanical troubles when the pressure P_0 is equal to or lower than the permissible compression pressure P_{c0} , i.e. when $P_0 \leq P_{c0}$ (E1). Curve E in FIG.4 is a cylinder pressure curve when the compression pressure is abnormally low.

Next the ratio of the maximum cylinder pressure P_p to said compression pressure P_0 at a predetermined crank angle in the compression stroke P_p/P_0 is calculated and the calculated maximum pressure ratio P_p/P_0 is compared in a maximum cylinder pressure judging means(step) with the predetermined permissible maximum pressure ratio P_{p0} which is the maximum permissible pressure ratio, and it is judged that the maximum cylinder pressure P_p is abnormally high compared to the design value(normal value) when said calculated maximum pressure ratio P_p/P_0 is equal to or exceeds said permissible maximum pressure ratio P_{p0} , i.e. when $P_p/P_0 \geq P_{p0}$ (E2) or when the number of operation cycles N_h in which said maximum pressure ratio P_p/P_0 is equal to or exceeds the predetermined pressure ratio P_{h1} , i.e. when $P_p/P_0 \geq P_{h1}$ (E3) is equal to or exceeds the permissible number N_{h0} , i.e. when $N_h \geq N_{h0}$ (E4).

Then it is judged by a knock judging means(step) that knock

is occurring in the combustion chamber 44 when the number of cycles S_n in which said maximum pressure ratio P_p/P_0 is equal to or exceeds the predetermined permissible pressure ratio of knock P_{h2} , i.e. when $P_p/P_0 \geq P_{h2}$ (E5) in a plurality of past cycles before the time point of judgment is equal to or exceeds the permissible number S_{n0} , i.e. when $S_n \geq S_{n0}$ (E6). Curve B in FIG.4 is a cylinder pressure curve when knock has occurred. In this case, the opening of the gas supply valve 7 is decreased to decrease the supply of recovered methane gas.

Then, in the misfire judging means(step), when said maximum pressure ratio P_p/P_0 is equal to or smaller than the predetermined minimum permissible pressure ratio P_n , i.e. when $P_p/P_0 \leq P_n$ (E7), and when the combustion pressure ratio P_1/P_0 , which is the ratio of the pressure P_1 at a predetermined crank angle in the combustion stroke to the pressure P_0 at a predetermined crank angle in the compression stroke shown in FIG.4 is calculated and the calculated combustion pressure ratio P_1/P_0 is equal to or smaller than the predetermined permissible pressure ratio P_m of misfire, i.e. when $P_1/P_0 \leq P_m$ (E8), misfire is judged to be occurring. In this case, the opening of the gas supply valve 7 is increased to increase the supply of recovered methane gas.

In this case, a predetermined crank angle θ_1 in the combustion stroke at which pressure P_1 is detected is determined at the position of crank angle symmetrical with regard to the top dead center to the position of a predetermined crank angle $-\theta_1$ in the compression stroke at which pressure P_0 is detected, as shown in FIG.4.

Like this, by using pressure ratio, not pressure itself,

to diagnose combustion conditions and judge how to control, more accurate combustion control can be achieved.

Next, the outline of the electric generating system adopting said methane gas engine will be explained with reference to FIG.5. The gas engine is installed near a coal mine, and recovered methane gas recovered through the bore hole for degassing for the sake of safety by means of a vacuum pump is supplied as fuel to the gas engine through piping.

On the other hand, ventilated methane gas exhausted from the mine cavity and the coal face together with ventilation air is introduced to the inlet pipe of the engine.

Said gas engine E can be connected with a electric generator G, and the exhaust gas of the gas engine E can be introduced to a boiler B to produce steam. The steam is used for the utility equipment in the mine premises, the electric power generated by the generator G is used for the utility equipment in the mine premises by way of a transformer facility and surplus electric power is supplied (sold) through power lines to users as commercial electric power.

The exhaust gas from the boiler B is released to the atmosphere. However, in this case, carbon dioxide produced by the combustion of coal mine methane gas is released as the exhaust gas. As the greenhouse effect index of methane is 21 and that of CO₂ is 1, the reduction of 20 times the greenhouse effect index of carbon dioxide is achieved. This reduction of greenhouse effect index can be traded as carbon dioxide emission credit.

Next, a business model of said gas engine electric generating system will be explained with reference to FIG.6 ,in consideration of a case of establishing a gas engine

electric generating system in a coal mine in China, for example.

Enterprising bodies of the gas engine electric power generating system are government-owned enterprises, mine owner companies, owners of steel, chemistry, electric power related enterprises, engineering companies, etc. The enterprising bodies may be institutions specifically established for constructing the electric power generation plant.

The enterprising body applies to the World Bank or ODA of Japan, etc. for financing or loan aid and at the same time applies for credit approval on the condition that that it establishes the gas engine electric power generating system in a coal mine in China. Approval is to be awarded by CDM Committee or the Committee of Article 6. The endorsement by the host country and acknowledgement by the investing country are necessary, and there may be the case that the investing country is other than Japan. Upon applying, if carbon dioxide emission credit is offered as security, the enterprising body can get fund easier.

The enterprising body reports to the U.N. or the Japanese Government of the reduction of greenhouse effect index and register this carbon dioxide emission credit on the emission credit market to prepare for trading with credit surcharge payment obligators.

After getting financing from the Asian Development Bank, etc., the enterprising body pays for principal parts to purchase the principal parts and complete the gas engine electric power generating system.

The enterprising body can get not only profit through

selling the electricity produced by the operation of the gas engine electric power generating system, but also can achieve the reduction of 20 times the greenhouse effect index of carbon dioxide. With the profit obtained by selling the carbon dioxide emission credit to credit surcharge payment obligators on the market, the loan can be refunded in a short period. Thus, the enterprising body can get profit dually.

The table of FIG.7 shows a worldwide spreading effect of the implementation of the present invention. In the left column of the table, regional total amount of coal mine methane gas emission in the world is shown.

If it is assumed that each country utilizes one third of recovered methane gas for the gas engine electric power generation system, generation capacity is 5180 MW, and production of electric power is 45 billion kWh/year, which corresponds to the case that 50~100 large nuclear power plants are established. The reduction in CO₂ of 20million ton/year can be achieved, which corresponds to 20% of total amount of CO₂ emission of Japan.